Expanding the Haptic Experience by Using the PHANToM Device as a Camera Metaphor

Joan De Boeck, Chris Raymaekers, Karin Coninx
Expertise Center for Digital Media
Limburg University Center
Wetenschapspark 2, B-3590 Diepenbeek, Belgium
{joan.deboeck, chris.raymaekers, karin.coninx}@luc.ac.be

Abstract: *Many applications that support force feedback make use of a haptic device (such as the PHANToM) used for pointing operations, combined with a second device, mainly used for navigation (such as a 3D mouse). In this research we formally assess the user's performance in a setup in which we use the PHANToM device for camera manipulations. This allows us to eliminate the second device and to free the user of the mental load to drive two different devices. Additionally, when using Sensable's PHANToM as a camera device, we will look into the effect of the additional force feedback.*

1. Introduction

Most desktop haptic applications consist of a two-device setup. The haptic device, mostly manipulated with the dominant hand, is used for pointing and manipulation operations. A second device (typically a 3D mouse) is used for navigation operations.

In the context of our research, very little can be found in literature about integrating forces in camera manipulations. In the early 90's efforts have been made in defining the best navigation metaphor [1] for a certain task in a virtual world. *Flying vehicle* and *Scene in hand* are the most commonly known. Other work has been done in improving navigation and wayfinding methods in virtual environments [2]. In some research systems hand-held miniatures [3] or Speed-coupled Flying [4] are presented to facilitate the user's interaction. A usability test by T.G. Anderson [5] provides evidence that additional force-feedback results in better performances when compared to the 2D navigation interface of CosmoPlayer. In this paper, based on Anderson's work, we introduce a fairly new variant on the "Eyeball in hand" navigation metaphor presented in [1] and focus on the comparison with the LogiCad Space Mouse [6].

In the next section we explain our "Camera in Hand" metaphor as a variant of the "Eyeball in hand" navigation metaphor. Afterwards, the experimental setup used to assess users' performance when navigating with this metaphor is described. The results of the formal evaluation are summarized and discussed. Finally, conclusions with regard to the usefulness of the proposed metaphor are formulated.

Fig 1. PHANToM as a camera device with virtual guiding plane

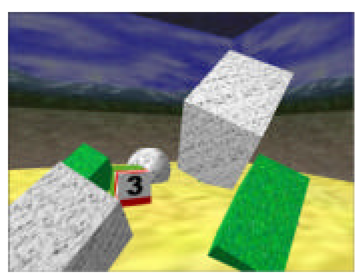

Fig 2. Virtual arena in which users have to locate the number

2. Eyeball in Hand/Camera in Hand

A possible implementation of the *eyeball in hand* metaphor is to use a Polhemus tracker as a virtual eyeball, which can be moved about the virtual scene. However, this manipulation method appeared to imply a confusing mental model in which disorientation is a common problem. In former research in our lab the *Eyeball In Hand*-metaphor has been extended to a MicroScribe device [7][8]: by moving the MicroScribe's stylus with the non-dominant hand, the virtual camera is repositioned. By defining the viewpoint in such a manner that it matches the direction of the stylus, disorientation will be avoided. As we are not actually handling an eyeball anymore, but rather a pen-like object, we will now call this extension the *Camera In Hand* Metaphor.
This paper adopts the latter metaphor for the PHANToM haptic device, and extends it by applying additional force-feedback. Informal testing taught us to set up a horizontal virtual plane (as shown in fig. 1) as the most useful feedback. This allows the user to easily walk forth and back in this plane. When changing the viewpoint's altitude the user has to act against the resistance of the PHANToM. A formal experiment, described below, was set up in order to formalize and detail the results obtained by informal testing.

3. Experimental Setup

The aim of our research was to formally compare this new metaphor and camera device to another existing 3D device. For this comparison condition we have chosen to use the LogiCad SpaceMouse in a "Flying Vehicle" metaphor.
Twenty-two volunteers with mixed experiences in virtual environments participated in the experiment. Most of the subjects are in their late twenties or early thirties, although 4 of them were above the age of 40. All subjects were right-handed and one third of the population was female.
All of the participants had to navigate in a virtual arena to locate and read a digit on a red-white coloured object (see fig. 2). This test had to be performed in three conditions; each condition consisted of 15 trials. The first condition measured performance with the SpaceMouse, the second looked at the PHANToM device without force feedback and finally the PHANToM device with force feedback has been tested. To eliminate transfer effects, the order in which to take the experiments was counterbalanced. During each trial the elapsed time and the total traveling distance had been logged. Finally, at the end of the test a comparative questionnaire had to be filled-up by the subjects. We have to note that one of our 22 test persons had trouble in performing the tasks in all conditions. Since his results exceeded 12 times the standard deviation, we have omitted those values.

4. Results

Chart 1 shows us the median values of the completion times of all subjects, per trial in each condition, which gives us a first impression of the results.

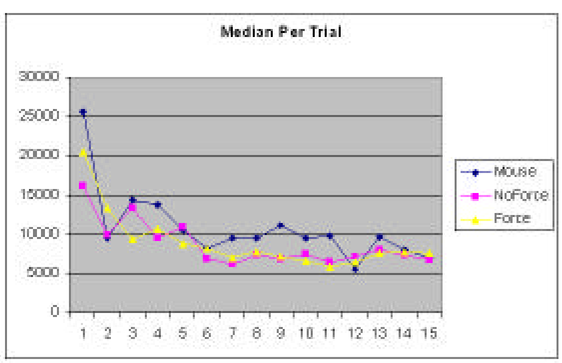

Chart 1. Completion Time (ms). Median values per trial

In our further analysis[1], we consider the first 5 trials for adaptation to the proposed input devices, and so leave them out of our computations[2]. As can be seen from chart 1 and table 1, the average completion time in both PHANToM conditions is slightly better than the SpaceMouse. With a P-value of 0.12, there is no significant difference, however.

[1] Using ANOVA

Mouse	13333 ms
PHANToM Force	10256 ms
PHANToM NoForce	9499 ms

P-Values	
Condition[Mouse-PH no]	0.1231
Condition[PH Fo - PH no]	0.8241

Table 1. Averages and P-values over all subjects

Because of the relative heterogeneity of our population, we have divided all subjects in four categories depending on their experience in 3D navigation: no, little, much and very much experience. Statistically, the groups with little, much and very much experience behave the same. Therefore, in our further analysis, we consider two levels of experience: novice (users without any 3D navigation experience) and experienced (all the others).
If we look at the average completion times in table 2, we can see there's still no significant difference between any of the conditions in the experienced group. However, we now notice a strong significant difference in completion times between the SpaceMouse and the PHANToM conditions among the novice users.

	Novice Users	**Experienced Users**
Mouse	17263 ms	9760 ms
PHANToM Force	9381 ms	11060 ms
PHANToM NoForce	9007 ms	9941 ms
P-Value		
Condition[Mouse-PH no]	<.0001	0.4922
Condition[PH Fo - PH no]	0.0507	0.2636

Table 2. *Averages and P-values per category*

A subjective questionnaire, filled up by all subjects after the test, shows us that experienced users significantly prefer the SpaceMouse over the PHANToM. On the other hand novice users choose one of both PHANToM conditions.

	Novice	Expert
Mouse	2	10
NoForce	5	1
Force	3	0

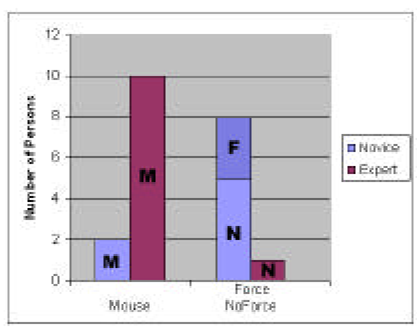

Fig. 3. *Subjective preference per category*

5. Discussion

As can be seen from table 2 experienced users objectively do not perform different in one or the other condition. If we look at the measurements of the novice users, we see a dramatic improvement when using the PHANToM. Compared to the values of the experienced category, we can notice that the values of the novice users using the PHANToM condition are similar. This means we can conclude that our *Camera In Hand* metaphor provides a possibility for the inexperienced user to perform equally to their experienced colleagues.
However we can also conclude that the addition of force-feedback, which implements a horizontal guiding plane, doesn't offer any advantages. There's even advantage for the no-force condition, though the difference is insignificant.

[2] This is supported by our results, as can be seen in chart 1.

As the performances of the experienced users are similar in all conditions, we have to ask why they collectively choose for the SpaceMouse condition. Our experienced users all spend several hours a day on a computer and all have their 3D experience playing games with mouse and keyboard. For that reason we suspect those users to have certain expectations and so feel more familiar with the SpaceMouse. In addition, some of those users report the limited workspace and tiring pose when using the PHANToM as a disadvantage.

6. Conclusion and future work

In this work we presented a 3D camera metaphor using the PHANToM device with and without force feedback. This metaphor can eliminate the use of a second input device in a haptic setup. The performances of those conditions have been measured and compared to the navigation with a SpaceMouse in a formal usability test. As a conclusion we can state that, using the PHANToM, novice users act in the same way with the *camera in hand* metaphor as the experienced users. When those users are using the SpaceMouse there is a strong performance penalty. However, experienced users mostly choose for the SpaceMouse, while they perform equally in all conditions. Finally, we also can conclude that additional force feedback in a sense of an additional guiding plane doesn't offer any benefits in this test.

We believe the *camera in hand* metaphor will be of interest to introduce the novice user into 3D environments, but it can also be useful when manipulating a scene that is rather centralized in a limited volume. Although additional force feedback doesn't seem to offer any benefits, we think, dependent on the task, additional stability can be obtained by finding a appropriate force factor, which is possibly somewhat smaller than the resistance force in our test.

In our future work, we want to evaluate the effect of additional functionality to step out of the limiting workspace of the PHANToM. This can be achieved by e.g. homing the PHANToM without changing the virtual camera, or by moving the virtual camera when the users pushes the outer limits of the PHATNoM's workspace [5].

7. Acknowledgements

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